Device and method for electrolytically treating electrically insulated structures

Description:

The present invention relates to a device and to a method for electrolytically treating electrically conductive structures that are electrically insulated against each other on surfaces of strip form work pieces in conveyorized plating lines.

For manufacturing chip cards (smart cards), price tags or identification tags for goods, foil-like plastic is utilized, the electrically conductive structures required for the electrical function desired being produced thereon.

Conventional methods utilize for example a copper coated material from which the desired metal pattern is produced using an etching process. In order to lower the cost of this method and to permit manufacture of structures finer than those that may be achieved with the etching process, there is an intention to produce the metal structures using electrolytic deposition. Such a known method for manufacturing antenna coils is described in U.S. Patent No. 4,560,445. According to this, the metal structure is produced on a polyolefin film using a method sequence involving the following method steps: swelling, etching, conditioning the plastic material for subsequent adsorption of catalytically active metal, depositing the catalytically active metal, printing a mask in the form of a negative image, accelerating the catalytically active compounds, electroless and electrolytic metal plating.

Processes for metal plating strips include *inter alia* electroplating methods. For many years, what are termed reel-to-reel processing equipments have been used for this purpose as conveyorized plating lines, the material being conveyed therethrough and brought into contact with the processing liquid during transport. The tapes are electrically contacted for electrolytic metal deposition. Contacting electrodes serve this purpose. For electrolytic treatment,

it is possible to dispose either the two electrodes, meaning the contacting electrode and the counter electrode, or the counter electrode only within the processing liquid in the processing lines.

DE 100 65 643 C2 describes a device for electroplating or for electrolytically etching conductive strip-form work pieces in which both the contact rollers serving for establishing electrical contact and the counter electrode are disposed within the bath. The problem of such arrangements is that the contact rollers are also metal plated within the bath so that there is a risk that the metal deposited onto the contact rollers damages sensitive foils.

For the purpose of avoiding or reducing metal deposits on cathodes within the electrolyte bath, WO 03/038158 A describes an electroplating equipment for reinforcing of electroplating structures that have already been configured to be conductive on a substrate in a reel-to-reel equipment for strips in which an anode and a rotating contact roller are located in an electrolyte bath. On its side turned toward the substrate, the contact roller is connected to the negative pole of a direct current source and on the side turned away therefrom, to the positive pole of the current source. This is made possible by segmenting the contact roller in a manner similar to that of the collector of a direct current motor. As a result, the metal deposited onto the contact roller during one revolution of the roller during normal operation can be stripped off by changing the potential toward anodic. A major disadvantage of this method is that the contact rollers are subject to heavy wear as a result of the permanent alternating operation of metal plating and deplating. This is the reason why very complicated and expensive coatings are to be used.

A basic disadvantage however is that only surfaces that are conductive over their entire area may be electrolytically treated, structures which are insulated against each other and are desirable for producing for example antenna coils however not.

DE 199 51 325 C2 therefore discloses a device and a method for the contactless electrolytic treatment of electrically conductive structures that are

electrically insulated against each other on surfaces of electrically insulated foil material, in which the material is conveyed on a conveying path through a processing equipment while being contacted with the processing liquid. During transport, the material is conducted past at least one electrode arrangement, each consisting of a cathodically polarized electrode and of an anodically polarized electrode, the cathodically polarized electrode and the anodically polarized electrode being in turn contacted with the processing liquid. A current source causes current to flow through the electrodes and the electrically conductive structures. The electrodes are thereby shielded from each other in such a manner that substantially no electric current is allowed to flow directly between the two oppositely polarized electrodes. A disadvantage of the method described is that the layer of metal deposited can only have a reduced coating thickness since as a result of the electrode arrangement metal is deposited on the one hand but is also, at least in parts, dissolved again on the other hand as the work piece is conducted past the cathodically polarized electrode.

As opposed to the previous electrode arrangements, U.S. Patent No. 6,309,517 describes a plating device for plating the entire surface of planar work pieces such as printed circuit boards in which the cathode is contacted outside of the electrolyte, metal being allowed to deposit as long as the material is in contact with the cathode and the electrolyte. For establishing electrical contact outside of the electrolyte cell, contact rollers, brushes or glides are used. The rollers are sealed toward the electrolytic cell by means of sealing rollers. This device however is not suited for processing strip form work pieces and insulated structures.

DE 100 65 649 A1 proposes a device for the electrochemical reel-to-reel processing of flexible strips having one conductive surface that has a cathodic contact roller located outside of the electrolyte. Special anode rollers around which the strips are wounded are rotatably disposed within the electrolyte. The anode rollers are thereby provided with an ion-permeable, electrically insulating layer that keeps the strips spaced a defined and as small a distance as possible apart from the anode. It is not possible to treat surfaces having structures that are electrically insulated against each other though.

As a result, the known methods do not permit to electrolytically treat surfaces with small structures that are electrically insulated against each other and that are deposited on an electrically insulated work piece in foil strip form in strip processing or conveyorized lines.

The problem underlying the present invention therefore is to avoid the disadvantages of the known electrolytic processing devices and methods. More specifically it is an object of the present invention to find a device and a method which permit continuous electrolytic treatment of small electrically conductive structures that are electrically insulated against each other on surfaces of electrically insulating foil material. A further object of the present invention is to find a method and a device which can be used for manufacturing foil material equipped with such type conductive structures and employed as a component of chip cards that serve for example to mark and automatically identify and distribute goods in distribution stations or as electronic identity cards, *e.g.* for access control. Such type electronic components are to be manufactured on an ultra large scale at very low cost. Still another object of the present invention is to find a method and a device which may be utilized for manufacturing printed circuit foils in the printed circuit technique and printed circuit foils having plain electric circuits such as for toys, in automotive engineering or in communications electronics.

The present invention provides the device in accordance with claim 1 and the method in accordance with claim 24. Preferred embodiments of the invention are recited in the subordinate claims.

It must be noted that, as used in this specification and the appended claims, the singular forms “a”, “an” and “the” include plural referents unless the content clearly dictates otherwise and *vice versa*. Thus, for example, reference to a plurality of work pieces includes a single work piece, reference to “a contacting electrode” includes reference to two or more of such contacting electrodes, and reference to “an electrolysis region” includes reference to two or more

electrolysis regions. Further reference to a work piece includes a foil strip, foil segments or panels and the like.

The method and the device of the invention serve to electrolytically treat more specifically small electrically conductive structures that are electrically insulated against each other on surfaces of electrically insulating strip form work pieces, more specifically of plastic strips (plastic foils) provided with such conductive structures. Such type structures have dimensions of a few centimeters *e.g.*, of 2 - 5 cm.

The work pieces can be processed on both sides (surfaces) or on one side only. In the first case, suited provisions for performing electrolytic treatment are to be made on both sides, in the latter case, on one side only.

The method and the device of the invention may also be used for through plating or metal plating *e.g.*, holes in the work pieces. Insulated structures on one side of the work pieces may for example be contacted with insulated structures or *e.g.*, semiconductor components such as capacitors or chips, provided on the other side.

The device of the invention comprises at least one arrangement comprising at least one contacting electrode for the work piece and at least one electrolysis region. In the electrolysis region, at least one counter electrode and the work pieces are contacted with the processing liquid. The contacting electrode is prevented from contacting the processing liquid. The contacting electrode and the electrolysis region are spaced such a small distance apart that small electrically conductive structures that are electrically insulated against each other and are to be processed on the surface of the electrically insulating foil strip form work pieces can be electrolytically treated. Within a processing line, several such electrode arrangements may be disposed one behind the other in series. Several such type processing lines may be connected in series.

The spacing (distance) between the contacting electrodes and the electrolysis region is to be as small as possible considering the size of the insulated

structures. In determining the spacing between the electrolysis region and the contacting electrode, the spacing between the beginning of the electrolysis region and the site on the contacting electrode that establishes sufficient contact with the work pieces is essential. This spacing is to be minimized. It should be chosen so that even electrically conductive structures of for example 5 cm may still be electrolytically treated with good results.

This arrangement of the contacting electrodes and of the electrolysis region permits to reliably metal plate even small structures that are electrically insulated against each other. The smaller the spacing between the contacting electrodes and the electrolysis regions, the smaller the differences in the coating thickness between the end areas (as viewed in the direction of transport) and the central areas of the structures which may be due to the fact that the structures are in contact with the contacting electrodes while being simultaneously in the electrolysis region for only a determined distance of the conveying path through the device of the invention. A layer that has the same thickness in the end areas and in the central area may be achieved when the spacings between the contacting electrodes in the device are so small that the structures can always be electrically contacted by at least one contacting electrode as the work pieces are conducted through the line. This is only possible if the structures are relatively large or if the spacings between the contacting electrodes are small. As the object of the invention consists in metal plating structures having dimensions of but a few centimeters as uniformly as practicable, the spacing between the contacting electrodes should not exceed a few centimeters either.

A particularly advantageous embodiment consists in providing at least two contacting electrodes, one of them being disposed on one side of a transport section leading through an electrolysis region and the other one on the other side of said transport section. In order to achieve the advantage of a very uniform electrolytic treatment as mentioned, the transport section leading through the electrolysis region may, in this case, be preferably chosen to be so short that the electrically conductive structures are in permanent electrical contact with one of the contacting electrodes.

In principle, a plurality of embodiments for implementing the principles mentioned herein above is conceivable. A particularly preferred first embodiment consists in providing at least one processing module containing the processing liquid and the at least one counter electrode, the work pieces being conducted therethrough in a horizontal direction of transport without direction change. In this case, the work pieces may be conducted either in a horizontal or in a vertical orientation, an inclined orientation being also possible. The processing modules each comprise at least one passage on the entrance side and one passage on the exit side thereof for the work pieces to enter the processing module and to exit said module. In this embodiment, the contacting electrodes are disposed on the passages. The electrolysis regions are located in the processing modules. This embodiment permits to achieve a very compact arrangement of the electrodes and of the electrolysis region that allows processing of even very small structures. Several such type processing modules may be disposed in series.

In another, second embodiment there is provided at least one tank containing the processing liquid and the at least one counter electrode. The conveying path on which the work pieces are conducted passes through the surface of the liquid into the tank, within the liquid to the counter electrodes and from there exits the tank through the surface of the liquid. In this case, the contacting electrode is disposed (in immediate proximity) to the surface of the processing liquid without contacting the latter. The closer to the surface of the liquid the contacting electrodes and the counter electrodes are disposed in this case (the contacting electrodes outside of the liquid and the counter electrodes within the liquid), the better the possibility to also electrolytically process very small structures. Thanks to this arrangement, contacting electrodes may more specifically be disposed in immediate proximity to the surface of the liquid at those sites at which the conveying path traverses the surface of the liquid. Inasmuch, the considerations made herein above apply. In placing squeezing rollers or air knives in a substantially upward oriented conveying path above the liquid surface level not far from a direction change into the horizontal, entrained

processing liquid may be stripped off by means of the rollers or the air knives and returned to the tank.

However, the contacting electrodes must be spaced a minimum distance apart from the surface of the liquid in order to prevent said electrodes from being brought into contact with the liquid.

To achieve as intensive an electrolytic treatment as possible, the conveying path in this embodiment may enter the tank through the surface of the liquid, traverse the liquid, exit the tank through the surface while passing through deviating means such as deviating rollers or cylinders several times.

The minimum size of the insulated structures to be processed is more specifically determined by the minimum spacing that is to be achieved between the contacting electrode and the counter electrode. The minimum spacing depends *inter alia* on the spatial dimensions of the contacting electrodes as well as on the distance separating the contacting electrodes from the electrolysis region. It is therefore advantageous to configure the contacting electrodes as rollers or as a plurality of reels that are arranged in a closely spaced apart relationship on an axis, the rollers or reels having a very small diameter so that the spacing between the longitudinal axes of the rollers or of the reel electrodes and the electrolysis region may be chosen to be very small. Thanks to the compact arrangement that can thus be achieved, electrolytic treatment of structures having dimensions on the order of 2 cm or even less may be achieved.

The attempt of reducing the minimum spacing between the electrodes by using for example round contacting electrodes that are as small as possible is often marred by the resulting mechanical instability of the contacting electrodes, more specifically when elastic contacting materials are being used. This problem may in any case be circumvented by using mechanically stable pinch rollers or reels that are disposed so as to fit against the contacting electrodes, thus stabilizing them, and at need even pressing them slightly together.

Instead of rollers and reels, brushes or electrically conductive, sponge-like devices that wipe the surface of the work pieces can be used as contacting electrodes.

The contacting electrodes are pressed by gravity and/or by the application of a spring force onto the surface of the work piece.

When adjusting the spacing between the contacting electrode and the surface of the liquid in the second embodiment, the contacting electrode is not allowed to be brought into contact with the processing solution. If the contacting electrode is for example used as a cathode in an electrolytic metal deposition process, the contacting electrodes must be protected against undesired metallization. It has however been found out that the spacing between the contacting electrodes and the surface of the processing liquid cannot be kept constant in practice. As a result, difficulties may arise when adjusting this spacing. These variations in the spacing are due to changes in the surface level of the processing liquid in the processing tank, said changes being caused for example by air being blown into said tank. Further, the liquid surface level may be lowered by evaporation or by processing liquid being dragged out of the tank by the work pieces conveyed through the processing liquid. On the other hand, the liquid surface level can also increase when dragged out or replenished processing liquid is returned to the tank.

To circumvent this problem, it has been found advantageous to insert in the region of the surface of the liquid between the contacting electrode and the processing liquid a partition member that allows the work pieces to pass therethrough but protects the contacting electrode from being wetted by the processing liquid. In order for the work pieces to be allowed to be conducted into and out of the processing liquid, this partition member must comprise passage openings such as slots through which the work pieces may be conducted. Such a partition member may for example be a suitably shaped liquid cover plate in which such a slot has been formed. Alternatively, two cover plates may be provided, said two cover plates being closely spaced together so as to form the slot.

The electrode arrangements of the invention may further comprise sealing members such as sealing walls with sealing lips and/or scrapers for retaining the liquid in the processing tank. Squeezing rollers may further be present, said rollers retaining the liquid, for example when the foil is being removed from the liquid, while reliably guiding the work pieces. Such type sealing members may be provided both at the passages provided in the processing modules in the first embodiment of the invention and in the partition members of the second embodiment. Said sealing means serve to retain as completely as possible the liquid within the electrolysis region so that no remaining liquid is allowed, as far as practicable, to get in touch with the contacting electrodes. Several such squeezing rollers (sealing rollers) may also be stacked one on top of the other so that they mutually seal during rotation.

If it is not possible to reliably prevent the processing liquid from getting into contact with the contacting electrodes, processing liquid that has exited the electrolysis region and reached the contacting electrodes may be removed by providing continuous or intermittent washing or spraying. In order to efficiently rinse the processing liquid off the contacting electrodes, the work pieces may be transported in a plane that is for example inclined to the horizontal at an angle of at least 5°, of about 70° at most and preferably at about 15°. Rinse liquid delivered to the contacting electrodes quickly drains off so that efficient removal of the processing liquid is made possible. Alternatively, processing liquid that has exited the electrolysis regions can also be removed by air jets, using air knives for example.

If the contacting electrodes are configured to be rollers, the work pieces, when they are treated on one side only, can be electrically contacted by means of a contacting roller and of a confronting current-less roller (supporting roller). When a conductive pattern is to be produced on both sides, the contacting rollers are to be provided on either side of the work pieces.

It is advantageous to configure the contacting electrodes and the counter electrodes to be elongate and to arrange them in such a manner that they

extend over the entire useful width of the work pieces. For this purpose, they may more specifically be disposed substantially parallel to the conveying path.

In the case of the second embodiment, the deviating rollers may also be utilized for establishing an electrical contact.

Roller-shaped contacting electrodes may preferably be manufactured from an elastic conductive material. This makes it possible to transfer a very high current onto the surface of the work pieces on the one hand and to reduce the spacing between the contacting electrodes and the electrolysis regions on the other, since the contact faces between the electrodes and the surface of the work pieces that determine these spacings are not narrow elongate areas as this is the case with rigid rollers but wide areas instead. Possible elastic contacting materials are metal/plastic composite materials, more specifically composite materials formed from an elastic plastic material having a large amount of electrically conductive fillers. They consist of elastomers as a binder such as caoutchouc, silicone or other elastic plastics that are electrochemically stable and of an electrically conductive filler. The binders also include conductive adhesives that will not fully cure as they are being used in the electronics manufacturing sector. The electrically conductive filler is admixed to such type materials during manufacturing. The metal plastic composite is thus obtained.

The fillers, which are also called inclusion components, preferably consist of metal in the form of powders, fibers, needles, cylinders, spheres, flakes, felt and other forms. The amount of filler relative to the entire contacting material amounts up to 90 % by weight. As the amount of filler increases, the elasticity of the metal plastic composite decreases and the electric conductivity increases. These two values are adjusted to the application case of concern. All of the electrochemically stable materials that are also electrically conductive are suited for being used as a filler. Current fillers are for example titanium, niobium, platinum, gold, silver, special steel and electrocoal. Platinum plated, silver plated or gold plated particles, such as spheres made from titanium, copper, aluminum or glass, may be used for example.

As the distance between the counter electrodes and the conveying path for the work pieces is adjusted to be as small as possible in order to achieve uniform electrolytic treatment, a metal layer of uniform thickness for example, even at high cathodic current density, there is a risk of an electrical short being created between the work piece and the counter electrode in the event that these are brought into undesired contact. In order to reliably avoid this risk, the counter electrodes may be provided with an ion-permeable, electrically non-conductive coating (an insulating layer) that is preferably soft and permeable to liquid. The spacing between the counter electrodes and the work piece may thus be minimized in that the counter electrodes with the insulating coating are brought near the surfaces of the work piece so that the coatings get in touch with the surfaces of the work piece.

In the event that the spacing between the counter electrodes and the conveying path is adjusted to be so small that the coatings on the counter electrodes wipe over the work pieces as they are being conducted past the electrodes, the coatings can preferably be wedged between the surfaces of the work piece and of the respective one of the counter electrodes. For this purpose, the coatings may project more specifically beyond the gaps formed by the counter electrodes and the surfaces of the work pieces, be thicker on the side of the cell walls that is turned away from the electrolysis region and thus protrude beyond the gap width and hold tight on the outer sides of the cell walls.

In order to prevent processing liquid from exiting the electrolysis region in the latter embodiment, lock chambers may further be provided within the processing module, said chambers being disposed directly before or behind the electrolysis region as viewed in the direction of transport. As a result, further partition walls are provided within the processing module, said walls separating the electrolysis region from the lock chambers. Accordingly, the lock chambers are defined by the partition walls and by the cell walls. In this embodiment, the lock chambers may be sealed against the outside by means of the sealing walls having sealing lips described herein above.

In order to prevent particularly thin work pieces from warping, the counter electrodes may for example be rotatably carried with their surface rotating at the same speed as the contacting rollers. The counter electrodes and the contacting electrodes may for example be motor driven with the work pieces being rolled on the anodes, so that they also serve as conveying members. The counter electrodes may be configured in different ways. They may be formed as a plate or as an expanded metal. Various types of counter electrodes may be combined. In order to prevent depletion of active chemical substances at the surface of the work pieces, fresh electrolyte may continuously be fed from the interior of a counter electrode. Therefore, counter electrodes made of expanded metal are preferred. This makes it possible to work at high cathodic current densities without burns occurring during electrolytic deposition.

In the event of electrolytic metal deposition, the contacting electrode is cathodically polarized and the counter electrode anodically (anode). Both soluble and insoluble anodes may be used as counter electrodes. Round flood anodes or anode rollers made of insoluble metal about which, in the second embodiment of the invention, the work pieces are being wound and thereby turned round may for example be used. Flood anodes comprise a hollow space into which processing liquid may be pumped and out of which the liquid may then be forced under pressure through openings in the anode shell. The to be treated surfaces of the work pieces may thus continuously be efficiently supplied with fresh processing liquid. The dimensions of the anodes are preferably the same as those of the work pieces.

If the device in accordance with the invention is utilized for electrolytic metal deposition in the first embodiment, the anodes *e.g.*, flood anodes, in the processing liquid may be configured to be elongate and oriented substantially normal to the work pieces. In a particularly advantageous embodiment, the work pieces may be conducted past a non-conductive, preferably soft, liquid and ion-permeable coating provided on the anode without an electrical short being created. This arrangement is provided in the processing modules mentioned herein above that may be equipped, in addition to the anodes, with electrolyte feed and discharge lines. In order to seal the module against leakage of liquid, it

is provided with walls on all sides, said walls being for example provided with passage openings, preferably slots, for the work pieces. These walls provided with slots are disposed on the entrance and on the exit side of the module and additionally comprise the aforementioned sealing members. The sealing members prevent greater amounts of electrolyte from escaping from the cell and thus prevent metal to deposit on the cathodic contacting elements. The sealing members may for example be sealing walls with sealing lips that wipe over the work pieces without destroying them. The liquid is thus prevented from exiting the module. If particularly sensitive foils are to be processed, the elastic sealing lips may be combined with sealing rollers. The diameter of all of the rollers must be kept as small as possible in order to permit processing of the small conductive insulated structures the length of which ranges between 30 and 45 mm and less. The lower limit for the diameter is dictated by the mechanical stability required for the rollers being pressed against the work pieces.

In order to reliably provide a particularly compact construction with minimal spacings between the counter electrodes and the contacting electrodes, the contacting electrodes and the counter electrodes can be accommodated as compact units on common carrier frames.

The device in accordance with the invention is preferably a component part of strip processing lines comprising each at least one first and one second storage facility *e.g.*, storage drums, for storing the work pieces. Such type processing lines often further comprise conveying members for conveying the work pieces through the processing line from the at least one first storage facility to the at least one second storage facility. Additionally, means for guiding sensitive work pieces so that they keep a precise straight course, for example lateral guide rollers and means for modifying the position of the conveying reels, may be provided. For this purpose, sensors may be provided along the conveying path, said sensors continuously registering the position of the outer edge of the work pieces and modifying the means for conveying and/or guiding the foil upon detection of nonpermissible deviations.

The device is more specifically suited for depositing metal on thin work pieces in strip form such as foils. Such type foils may for example consist of polyester or polyolefin and of the derivatives thereof, more specifically of polyethylene and polyvinyl chloride (PVC). The foils may have different thicknesses ranging for example from 15 to 200 μm; PVC foils for example may have a thickness of up to 200 μm, depending on the application case.

The device as claimed may more specifically be utilized for manufacturing coil shaped structures on plastic foil material. Such type coil shaped structures are used as antennas that are utilized for contactless data transmission on a data carrier (Smart Cards). Carriers comprising such type antennas may for example carry an integrated circuit that is electrically wired with the antenna so that electric pulses generated in the antenna are sent to the integrated circuit where they are stored for example or the data received by means of the antenna are processed as an electrical signal.

Signal processing permits to convert the data supplied, taking for example into consideration other data already stored, the thus obtained data being in turn stored and/or delivered to the antenna. These data, which are then transmitted by the antenna, can be received in a receiving antenna so that the data emitted may for example be compared to the data received by the antenna on the data carriers. Such type data carriers may for example be utilized in goods logistics and in retail trade *e.g.*, as contactless readable price tags or identification tags on goods, further as person related data carriers such as ski passes and identity cards for access control or as identification means for automotive vehicles.

Further application fields of the foils provided with the electrically insulated metal structures are for example the manufacturing of simple electric circuits such as for toys or wrist watches, in automotive engineering or in communications electronics. These materials may further be utilized for active and passive electromagnetic screening of apparatus or as screening grid materials for buildings as well as on textiles for clothing.

The data carriers can be made from foils such as polyester foils, polyolefin foils or polyvinyl chloride foils, on which the electrically isolating structures have been electrolytically produced, using the device of the invention. For this purpose, the foils provided with metallized structures and manufactured using the device are divided, according to the structure patterns produced thereon in multiple printed panels, into discrete foil segments corresponding to the size of the respective data carriers. The integrated circuits may then be deposited onto the foil segments and the metal structures electrically connected to the integrated circuit deposited. A bonding process may more specifically be utilized for this purpose. The integrated circuits can be deposited not only in the form of a chip that has not yet been provided with a carrier, but may also be deposited onto a carrier such as a TAB carrier and placed onto the foil. Once the integrated circuit has been electrically contacted, the foil segment can be processed into the finished data carrier, said segment being further laminated with another foil so as to form a card with the antenna being welded therein.

More specifically, the electrically isolating structures on the data carrier can be manufactured in the following manner:

The foil material, which is preferably in strip form and has for example a thickness ranging from 20 - 50 µ and a width of 20 cm, 40 cm or 60 cm, is provided on a storage drum around which the foil is wound.

At first, the strip is provided with the structure to be produced in that for example an activator varnish or an activator paste is printed onto the surface of the foil. For this purpose, said varnish or paste may for example contain a noble metal compound, more specifically a palladium compound, preferably an organic palladium complex. The varnish or paste moreover contains a binding agent as well as further current constituents such as solvents, dyes and thixotropic agents. The varnish or paste are printed preferably by means of a roller onto the foil conducted past said roller, more specifically with an offset, a gravure or a lithographic printing process. For this purpose, the varnish or paste is transferred from a reservoir onto a dispenser roller, from the dispenser roller onto the printing roller and from there onto the foil. Excess varnish or excess

paste is removed from the dispenser roller and from the printing roller using suited scrapers. The printing roller may for example be coated with hard chromium. The foil is pressed against the printing rollers by means of a soft counter roller ("soft roller") for efficient inking. In a station following the activator printing station, the ink printed on the foil is dried. For this purpose, the strip form foil material is conveyed through a drying path that is for example formed from IR radiators or hot air ductors or that may also comprise UV radiators if the binding agent in the activator varnish or the activator paste is to dry reactively under the action of UV radiation (preferably without solvent). These drying apparatus are preferably disposed in a drying tunnel through which the strip form material is conveyed. After having passed the drying station, the strip form material reaches another strip storage facility that may more specifically be formed from a drum. On its way from the first storage drum from which the material is unwound to the second drum on which the material is recollected, said material is guided and stretched over reels (reel-to-reel process).

The strip form foil that has been printed with the activator varnish or with the activator paste is first electrolessly and then electrolytically metal plated in order to form the metal structures.

For this purpose, the foil that has been printed with the activator varnish or paste is unwound from the storage drum and conducted through various consecutive processing stations of a processing line, the strip form material being guided over (deviating) reels and stretched (reel-to-reel method). In principle, it is also possible to convey the strip form material directly from the printing process to the wet-chemical treatment without any further intermediate storing of the material.

In a first treating step the printed material is transferred into a reductor that usually is a strong reducing agent in an aqueous solution such as sodium boron hydride, an amino borane such as dimethyl amino borane or a hypophosphite. In the reductor, the oxydated noble metal contained in the varnish or the paste is reduced to metallic noble metal, for example to metallic palladium. After reduction, the strip is fed to a rinsing station where excess reductor is water

rinsed. A spray sink is preferably utilized for this purpose. Next, a very thin layer of copper (of 0.2 - 0.5 µm thick) is electrolessly deposited onto the activator structures. Copper deposition onto the structures is initiated by the noble metal nuclei formed in the reductor, no copper being deposited onto the non printed areas. A current bath containing formaldehyde as well as tartrate, ethylene diamine tetraacetate or tetrakis-(propane-2-ol-yl)-ethylene diamine may be utilized as the copper bath. After copper plating, the strip form material is conveyed to a rinsing station in which excess copper bath is stripped off by spray rinsing with water.

Next, the strip form material is fed to the device of the invention in which the now electrically conductive structures are selectively coated with further copper. All of the known electrolytic copper plating baths can be used for electrolytic copper deposition, for example baths containing pyrophosphate, sulphuric acid, methane sulfonic acid, amido sulfuric acid or tetrafluoroboric acid. A particularly suited bath is a sulfuric acid bath that may contain copper sulfate, sulfuric acid and small amounts of chloride as well as additives such as organic sulfur compounds, polyglycolether compounds and polyvinyl alcohol. The sulfuric acid bath is preferably operated at a temperature near room temperature at as high as possible a cathodic current density. If the speed at which the foil strip is conveyed through the device of the invention is 1 m/min, a cathodic current density of for example 10 A/dm^2 (active structure surface) could be adjusted so that copper be deposited at a rate of about 2 µm/min. With a line of about 2.5 - 7.5 m in length, a copper layer of from 5 - 15 µm thick can be deposited in this way.

Electric current can be supplied to the foil strip and to the anodes in the device in accordance with the invention in the form of direct current or of pulsed current. The latter is advantageous for producing as high a current density as possible since a copper layer exhibiting good properties (high surface quality such as gloss, lack of roughness, uniform coating thickness, good ductility, electric conductivity) can still be deposited under these conditions. For this purpose, what is termed reverse pulsed current is preferably utilized, *i.e.*, a pulsed current that comprises both cathodic and anodic current pulses. In

principle, unipolar pulsed current is of course also advantageous. Using reverse pulsed current, the pulse heights of the cathodic and anodic current pulses, the respective pulse widths and at need the interpulse pauses as well are optimized in order to optimize the deposition conditions.

Since electrolytic copper plating is performed using insoluble anodes in the device of the invention, copper ions cannot be subsequently dissolved by electrolytically dissolving copper anodes. In order to maintain the concentration of copper ions in the deposition solution, compounds of a redox system, more specifically Fe^{2+} and Fe^{2+} compounds such as $FeSO_4$ and $Fe_2(SO_4)_3$ are preferably added to the bath. The Fe^{2+} ions contained in the bath oxidize at the insoluble anode to form Fe^{3+} ions. The Fe^{3+} ions are transferred to another tank containing metallic copper pieces (regenerating tower). In the regenerating tower, the copper pieces oxidize under the action of the Fe^{3+} ions to form Cu^{2+} and Fe^{2+} ions. As the two reactions (anodic oxidation of the Fe^{2+} ions to form Fe^{3+} ions and oxidation of the copper pieces to form Cu^{2+}) proceed while concurrently, the concentration of copper ions in the deposition solution can be kept largely constant.

After the foil strip has been passed through the metal plating device of the invention, the material is again conducted to a spray sink in which excess deposition solution is rinsed off. Then, the strip material is transferred to a device in which it is contacted with a passivation means that is intended to prevent copper from tarnishing. Prior to winding the strip form foil material onto another storage drum, the material is dried in a drying station. For this purpose, the apparatus utilized may be similar to those used for drying the activator varnish or the activator paste.

The work stations utilized for performing the method steps mentioned are equipped with suited guide and transport reels or rollers as well as with apparatus for processing the processing liquids such as filter pumps, dosing stations for chemicals, as well as with heating and cooling systems.

The invention will be explained with reference to the Figs. The Figs. show:

Fig. 1 a cross-sectional side view of a horizontal processing line in accordance with the present invention in a first embodiment in two variants;

Fig. 2 a cross-sectional side view of a single processing module of a horizontal processing line in the first embodiment;

Fig. 3 a cross section of a half of a single processing module of the horizontal processing line in accordance with **Fig. 1** as viewed in the direction of transport;

Fig. 4 a cross-sectional side view of a single module of a horizontal processing line in accordance with the present invention in a first embodiment in another variant;

Fig. 5 a cross-sectional side view of a horizontal processing line in accordance with the present invention in a second embodiment;

Fig. 6 a cross section through the horizontal processing line in accordance with **Fig. 5** in a detailed solution;

Fig. 7 a detail of the horizontal processing line of **Fig. 6**;

Fig. 8 a cross-sectional side view of the horizontal processing line in accordance with the present invention in the second embodiment in another variant;

Fig. 9 a cross-sectional side view of a modified implementation of the horizontal processing line of **Fig. 8**.

For closer description of the Figs. it is assumed that metal is deposited onto strip form foils in the devices in accordance with the invention and that cathodically polarized contact means and anodes employed as counter electrodes are provided for the purpose. Alternatively, the device can of course be utilized for carrying out other cathodic treatment processes as well. Further, the device in accordance with the invention may of course also be utilized for carrying out anodic processes, for example for anodic etching, chromatizing or anodizing (for example anodic electrolytic oxidation). In this case, the strip form foil is anodically polarized. A cathode is utilized as a counter electrode.

In the Figs. described herein after, like numerals have the same meaning.

Fig. 1 illustrates a first embodiment of the device in accordance with the invention. The size of the device shown in the Fig. may more specifically approximately match the actual size of the device. This means that the discrete modules **M** in the device have, as viewed in the direction of transport, a length of a few centimeters if electrically isolating structures respectively having dimensions on the order of a few centimeters are to be treated. Viewed in the direction of transport, the length of a single module **M** may for example be 4.5 cm. The length of the various modules (in this context the reader is referred to size **L** in **Fig. 2**) depends on the size of the structures on the foil strip **1**. The width of the discrete modules **M** depends on the width of the foil **1** to be processed. If for example a foil strip **1** having a width of 60 cm is processed in the device, the discrete modules **M** must also have a width on this order. As a result, the modules **M** are preferably elongate processing devices that extend substantially normal to the direction of transport (direction of transport denoted by an arrow in **Fig. 1**) over the entire width of the foil **1**.

The foil **1** is preferably provided in the form of a strip which is unwound from a reel that has not been illustrated herein and which, after having been conveyed through the device of the invention, is wrapped around another reel that has not been illustrated either (reel-to-reel).

The processing modules **M** are disposed along the conveying path of the foil **1** leading through the device so that the foil **1** is allowed to be conveyed through one module **M** after the other. The number of modules **M** depends on the processing time required in the discrete modules **M**: if a very thick copper layer is for example to be deposited e.g., a layer of 5 µm thick, with the foil strip **1** being intended to be conveyed at high speed through the device in accordance with the invention, *e.g.*, at a speed of 2 m/min, about 110 modules **M** having an active length of 4.5 cm are needed to be disposed behind each other if copper is deposited at a cathodic current density of 10 A/dm^2 (2 µm Cu/min). The term "active length" of a module **M** is to be construed as the length of the region within the module **M** in which metal is deposited onto the foil **1** conveyed therethrough.

The device in accordance with the invention illustrated in **Fig. 1** consists of a collecting tank **12** in which there are disposed three processing modules **M**. The collecting tank **12** consists of a tank bottom and of two vertical side walls extending parallel to the conveying path on which the foil strip **1** is being conveyed, said walls extending respectively in front of and behind the plane of the drawing and parallel to the direction of transport. Walls are also provided at the two vertical end sides, said walls being horizontally slotted for allowing the foil strip **1** to enter and exit the collecting tank **12**. This is shown in **Fig. 1** on the left hand side and on the right hand side respectively of the collecting tank **12**.

The foil strip **1** enters the collecting tank **12** through the horizontal slot provided in the entrance wall on the left side wall thereof and is conveyed through the collecting tank **12** in the horizontal direction and in a horizontal orientation. The foil strip **1** can be guided normal to the direction of transport so as to be slightly inclined relative to the horizontal in order to aid the liquid in flowing off the surface of the foil strip **1** over the lateral side border of the strip **1** that is oriented parallel to the direction of transport. The foil is conveyed through three processing modules **M** that are disposed behind each other in the direction of transport. After the foil strip **1** is conveyed through the last module **M**, it exits the collecting tank **12** through the horizontal exit slot provided in the exit wall.

The foil strip **1** is advanced within the collecting tank by means of transport means and is also guided thereby. The transport means may for example be the contact rollers **6** and the sealing rollers **7** that will be both described in closer detail herein after if these rollers are motor driven. In addition to these rollers, other transport means that have not been illustrated herein may be provided such as transport wheels that are secured to motor driven axes that extend over the conveying path substantially normal to the direction of transport or transport rollers that are disposed in the same manner. The transport wheels on the axes may be distributed over the entire width of the foil strip **1** or only be disposed in the border region of the foil strip **1** for example. In order to guide the strip **1** so that it is exactly parallel to the direction of transport, the transport means may also be slightly deviated from the conveying path or from the preferred axis direction normal to the direction of transport in order to ensure

level guidance of the strip **1** on a straight line. Sensors that are not shown in the Fig. and that continuously detect the precise position of the strip permit to modify the orientation of the transport and/or guide rollers in order to permanently keep the foil on the same conveying path.

Processing liquid running off the processing modules **M** is allowed to accumulate in the lower part of the collecting tank **12.** The liquid level in the collecting tank **12** is labeled with reference numeral **15.**

The discrete modules **M** in the device can be configured to be identical or different. In the present case they are of identical configuration.

Each processing module **M** comprises a top and a bottom portion that are respectively disposed above and beneath the plane of transportation of the foil strip **1**. The walls of the modules **M** are indicated at **10.** These two portions form an upper electrolytic cell **2** and a lower electrolytic cell **3** that are filled with processing liquid. The two portions are built according to substantially the same principle. Both portions comprise anodes **4** that are oriented toward the plane of transportation and are disposed parallel to the plane of transportation on either side thereof. In the modules **M** the anodes **4** are secured to the module housing by means of suited holders **5.** On the faces of the anodes **4** located on this side as viewed from the plane of transportation, ion-permeable coatings (insulating layers) **13** are provided for preventing contact between the foil strip **1** and the anodes **4.** Without the coatings **13**, this could easily happen because the spacing between the anodes **4** and the foil strip **1** is preferably chosen to be very small. This small spacing permits to largely prevent non uniform electrolytic treatment at different sites on the electrically conductive structures so that a relatively high current density can be adjusted.

Within the modules **M**, there is the processing liquid that is supplied via electrolyte feed lines **11** to the inner volumes of the two portions of the modules **M.** As a result, the strip **1** located in the modules **M** and the anodes **4** are contacted with the processing liquid so that an electric current is allowed to flow

between the anodes **4** and the structures on the strip **1** that are electrically insulated against each other.

In order to electrically contact the structures that are electrically insulated against each other, the foil strip **1** is electrically contacted in accordance with the invention outside of the electrolytic cells **2, 3**. By electrically contacting the strip **1** very close to the region on the strip **1** in which the anodes **4** provide a largely homogeneous electrical field (electrolysis region), the structures on the foil **1** that are electrically insulated against each other can be electrically contacted with contact means while they still or already are within the regions mentioned. This makes continuous electrolytic treatment possible.

In the case shown in **Fig. 1**, contact rollers **6** are provided downstream and upstream of the left module **M** and contact brushes **14** downstream and upstream of the right module **M**, these contact rollers and brushes being employed as contact means and being oriented substantially normal to the direction of transport and over the entire width of the conveying path.

The contact rollers **6** can more specifically be metal rollers, for example rollers the outer contacting surface of which is made of special steel or of copper or rollers having an electrically conductive, elastic surface. In the latter case, the surfaces of the rollers **6** may for example be provided with an elastic plastic coating that is rendered electrically conductive by insertion of metallic particles.

The contact brushes **14** can be fibers made from copper or graphite for example that are secured on a brush base. The fibers may additionally be electrically insulated at the fiber shaft.

To allow the current to flow from the contact rollers **6** or contact brushes **7** via the structures that are electrically insulated against each other and the processing liquid to the anodes **4**, a current source that has not been illustrated herein is utilized, the poles of which are connected to the contact rollers **6** or the contact brushes **14** or to the anodes **4**.

In the case shown in **Fig. 1**, the strip **1** is electrically contacted by means of electric contact rollers **6** or contact brushes **14**, with said rollers **6** and brushes **14** not coming into contact with the processing liquid. For this purpose, the contact rollers **6** and the contact brushes **14** are located outside of the regions of the modules **M** that contain processing liquid.

Sealing rollers **7** are further provided, said sealing rollers largely preventing processing liquid from exiting the inner volume of the modules **M** and from reaching the contact rollers **6** or contact brushes **14**. For, if the contact rollers **6** or the contact brushes **14** were to come into contact with the processing liquid, metal could be deposited thereon. This is not desirable. The sealing rollers **7** are preferably elastic and are pressed against the surfaces of the foil strip **1**. As a result, they tightly fit against the surfaces of the strip **1**. Like the contact rollers **6** and the contact brushes **14**, they are disposed normal to the direction of transport and distributed over the entire width of the conveying path for the foil strip **1**.

Furthermore, elastic sealing walls **9** are provided for sealing the module housing against exiting liquid. For this purpose, the sealing walls **9** are secured to the end walls **10** of the module housing so as to provide a liquid tight sealing, preferably pressing tangentially against the sealing rollers **7**. In the case of the sealing rollers **7** being disposed downstream within a module **M** and of the sealing walls **9**, the latter are attracted toward the sealing rollers **7** by the rotation of the same due to the mechanical friction and the static pressure of the liquid within the electrolytic cell, thus providing efficient sealing of the module **M** against leakage of processing liquid into the liquid free space. By contrast, in the case of the sealing rollers **7** and the sealing walls **9** being disposed upstream, the sealing walls **9** would continuously be lifted from the sealing rollers **7** by the rotation thereof so that sufficient sealing against leaking liquid could not be provided. Therefore, auxiliary sealing rollers **8** are additionally provided in the entrance region of the modules **M**, said auxiliary rollers being preferably configured to have an elastic surface like the sealing rollers **7** and rolling on the sealing rollers **7**. In this case, the sealing walls **9** fit against the

auxiliary sealing rollers **8** and efficiently seal the module **M** against leaking liquid.

On the sides of the modules **M** that extend parallel to the direction of transport, sealing lips (not shown herein) are provided for sealing against leaking processing liquid. Since there are no contact means for electrically conductive structures in this region, efficient sealing is not absolutely necessary, though.

The top portion of the modules **M** can be configured to be removable for introducing the foil into the device. Corresponding holding elements (not shown) mounted to the lower portion of the module permit to securely retain the top module portion during normal operation and to firmly anchor it using *e.g.*, readily releasable wing nuts.

Fig. 2 shows a cross section of a module **M** in a collecting tank **12** that is filled to the bath surface level **15** with processing liquid that has run off the surfaces. The foil strip **1** enters the collecting tank **12** through a horizontal slot in the one end wall thereof and first comes into electrical contact with the contact brushes **14** via both sides of the material. Electric current is supplied to the electrically conductive structures on the strip **1** via the brushes **14**. The brushes **14** extend substantially over the entire width of the strip **1** so that all the structures on the strip **1** can be supplied with current. It is important that all the structures be touched by the brush fibers as they are conducted past the brushes **14**. As the structures extend in the direction of transport, they can be in electrical contact with the brushes **14** while being at the same time located within the electrical field of the anodes **4** in the electrolytic cells **2, 3**.

Very close to the brushes **14** and downstream thereof there are provided sealing rollers **7** that are disposed on either side of the strip **1**. Auxiliary sealing rollers **8** additionally roll on the sealing rollers **7**, sealing walls **9** providing a tangential seal. The elastic sealing walls **9** are secured to the cell walls **10** of the module **M**. Processing liquid is supplied from the collecting tank to the inner volume of the module **M** via electrolyte feed lines **11** and pumps and pipelines

(not shown). Excess processing liquid is returned to the collecting tank via electrolyte discharge lines **17** provided in the cell walls **10**.

After having been conducted past the seal, the foil strip **1** enters the inner volume of the module **M** in which it is exposed to the electrical field of the anodes **4** disposed above and beneath the plane of transportation. The anodes **4** are made of expanded metal, for example of platinum plated titanium. Ion-permeable coatings **13** are located between the plane of transportation and the anodes **4**, said coatings preventing an electrical short from developing upon contact of the anodes **4** with the electrically conductive structures.

After the foil strip **1** has been passed through the module **M** it is conducted past another pair of sealing rollers **7** that prevents liquid from exiting the module **M**. Sealing walls **9** that fit tangentially against the sealing rollers **7** and are secured to the cell end walls **10** additionally seal the inner volume against liquid leakage. Once the strip has passed the sealing rollers **7** it is brought into contact with further contact rollers **6**. The structures that are electrically insulated against each other and can no longer be contacted by the contact brushes **14** as they are conveyed through the module **M** are electrically contacted again as a result thereof.

Fig. 3 is a cross sectional view of a half of the view indicated at **"A"** in **Fig. 1**. Inasmuch, the reader is referred to the elements mentioned in the description of **Fig. 1** and labeled with the corresponding reference numerals.

On either side of the foil strip **1** guided here in a horizontal plane of transportation, anodes **4** that are also horizontally oriented and mounted on anode holding devices **5** as well as ion-permeable isolations **13** that directly fit against the anodes **4** are shown in the module **M** which, in the sectional view, is denoted by the cell walls **10**. The anodes **4** and the foil strip **1** define electrolytic cells **2, 3**.

Further, horizontally mounted sealing rollers **7** may be seen in the front view, said rollers being mounted on bearings **16** in one of the cell walls **10**. A

respective contour of the sealing rollers **7** is covered by the sealing walls **9** and is therefore shown in a dotted line. The sealing walls **9** extend toward the plane of transportation and tangentially fit against the sealing rollers **7**. They are secured to the cell end wall **10** so as to provide a liquid tight seal.

The processing liquid is supplied from the collecting tank **12** to the inner volume of the module **M** via electrolyte feed lines **11** and (not shown) pumps and pipelines and is allowed to run off via electrolyte discharge lines **17**. The liquid that has run off accumulates in the sump of the collecting tank **12** (which is indicated by the bath surface level **15**).

Fig. 4 shows another preferred embodiment of a module **M** in a collecting tank **12**. The view corresponds to the view shown in **Fig. 2**.

As contrasted with the module **M** shown in **Fig. 2**, the ion-permeable coating **13** is in direct contact with the passing foil strip **1**. The coating **13** concurrently performs the function of sealing the inner volume of the processing module **M** against the contacting electrodes **14**. In order to prevent processing liquid from directly reaching the contacting electrodes **14** through the coating **13**, the inner volume of the module **M** is bounded by additional inner partition walls **24**. On these inner partition walls **24** the coating **13** is secured on the entrance and on the exit side so as to be liquid tight. The coating **13** may additionally be secured to the cell walls **10** that extend alongside the conveying path. As the work piece **1** does not extend as far as the outermost region of the inner volume of module **M**, this additional fixation is not absolutely necessary.

Via electrolyte feed lines **11** the processing liquid is delivered to the anodes **14** formed from expanded metal, which it traverses before being supplied to the coatings **13**. Since the coatings **13** are formed from sponge-like or liquid absorbing material, they can become saturated and establish an electrolytic contact between the anodes **4** and the strip material **1**. Excess processing liquid can flow back to the collecting tank **12** in a direction transverse to the direction of transport.

Since, thanks to the capillary forces and the squeezing, the liquid is retained substantially within the isolating material **13** in the entrance and exit region of the inner partition walls **24**, there is a reduced risk that liquid exits the module **M**. Residual amounts of liquid that can exit the processing module **M** are discharged downward via the volume formed by the partition walls **24** and the cell wall **10** of the module on the entrance and on the exit side through the electrolyte discharge line **17** into the sump of the collecting tank **12**. As a result sealing lips **23** suffice to keep the contacting elements **14** largely free of liquid. On the exit side (downstream), two sealing lips **23** can be provided on the wall **10** of the processing module **M**, said sealing lips being secured both to the inner and the outer wall surface **10** in order to prevent processing liquid from exiting the module **M** as it is more easy for the processing liquid to exit the module **M** there than in the entrance region because of the forward movement of the strip **1**. As a result, the spacing provided between the contact brushes **14** (or, in the alternative, of the contact rollers **6**) and the electrolytic cells **2, 3** is very small. In order to prevent the friction resulting from the coating **13** coming into contact with the work piece **1** from causing the strip **1** to elongate, transport rollers **25** can be provided before and behind each module **M**. To regulate the pressure, more specifically in the lower module cells **3**, control valves can be mounted into the pipelines of the discharge lines **17**, said control valves adjusting the pressure to be constant within the cells **2, 3** through sensors provided in said cells **2, 3**.

As the insulating layers **13** continuously wipe over the foil strip **1** and disturb the diffusion layer on the work piece **1**, this implementation variant permits to adjust particularly high current densities.

Fig. 5 is a cross sectional side view through a horizontal processing line in accordance with the present invention in a second embodiment. The processing line comprises a collecting tank **12** in which there are disposed three processing modules **M** that are identical in construction. The processing modules **M** are disposed alongside the conveying path of the foil strip **1** through the device so that the foil strip **1** is allowed to be conveyed through one module **M** after the other. The discrete processing modules **M** substantially consist of the contact

rollers **6**, the anodes **4** comprising an ion-permeable isolation **13**, anode holders **5** and processing liquid (electrolyte). The processing liquid fills the collecting tank **12** to such an extent that the bath surface level **15** lies just underneath the contact rollers **6**.

The rollers **6** are arranged in such a manner that, at the deviating roller **18**, which, like the contact rollers, can be motor driven for assisting in transport, the substantially horizontally fed foil strip **1** is conveyed into the first module **M**, being passed in a vertical movement between the contact rollers **6** into the processing liquid. The two sides of the foil strip **1** are electrically contacted by the two contact rollers **6**. The anodes **4** are configured to be flood anodes made of an insoluble metal from the inner volume of which fresh electrolyte is continuously supplied for the deposition process. The flood anodes convey the foil strip **1** past the isolation **13** where it is metal plated before being drawn out of the electrolyte while being contacted anew at the other contact reels **6** located above the bath surface level **15**. After having been turned round by the other deviating reel **18**, the foil strip **1** is conveyed through the second module **M** and, after having been turned round anew by the third deviating reel **18**, conducted through the third module **M**. After having been conducted past the third module **M**, the foil is again turned round by means of a fourth deviating reel **18** before being finally horizontally led out of the processing line.

Fig. 6 illustrates a cross sectional detailed solution of two modules **M** of the horizontal processing line in accordance with **Fig. 5**, only one half of each module **M** being shown.

In this case, the device is characterized by the additional component parts, namely the partition member **21** with slots and sealing lips **23** (shown in **Fig. 7**) and the pinch rollers **22**. These component parts serve to protect the contact rollers **6** from the processing liquid. The pinch rollers **22** serve to increase the mechanical stability of the contact rollers **6**, which are configured to be particularly thin. The pinch rollers **22**, which fit directly against the contact rollers **6**, can press these together when the rollers **6** are elastic, thus making certain that the current is well transmitted even in the case of contact rollers **6** having a

very small diameter. This in turn permits to further reduce the spacing between the anode **4** and the contact rollers **6**.

In a special embodiment, the pinch rollers **22** can also perform the function of the counter electrode. For this purpose, the rollers have for example a spiral coating that is not illustrated in the Fig. and is deposited in the form of narrow strips on the conductive anode surface of the roller shaped anodes **4**. The spacings between the spiral helix remain exposed. The coating, which is deposited like a spring, rolls on the contact rollers **6**, pressing them against the work pieces **1**. Thanks to the spiral shape, the screening effect of the coating, which is not or but to a small extent ion-permeable, on the pinch rollers **22** acting as anodes exerts its effect permanently on other sites of the work pieces **1** and prevents them from being non-uniformly coated. The same effect can be achieved using ring shaped isolations that are mounted to the anodes so as to be offset from one module to the other.

In order to protect the contact rollers **6** from being metal plated by splashing processing liquid, the surface of the liquid is completely covered by a partition member **21** comprising a slot serving as a passage opening.

During electrolytic treatment the foil strip **1** is passed through the schematically denoted anode **4** comprising an isolation (not shown herein) in the first module **M**, the anode **4** almost touching the contact rollers **6**. The foil strip **1** is supplied from the inner volume of the anodes **4** through the slot in the partition member **21** directly to the contact rollers **6** without coming into contact with the processing liquid outside of the anode **4** like in **Fig. 5**. As a result, the amount of entrained processing liquid is minimized. Then, the foil strip **1** is turned round at the deviation roller **18** and conveyed into the second module **M**. It is thereby electrically contacted again at the contact rollers **6** and introduced through the slot in the partition member **21** into the anode **4** for further metallization.

Fig. 7 shows a schematic detail of the detailed solution for module **M** of the horizontal processing line of **Fig. 6**.

The foil strip **1** is passed between the contact rollers **6** that are spaced in close proximity to the anode **4** and between the sealing lips **23** that are disposed at the slot of the partition member **21**. It can be seen that the partition member **21** is capable of efficiently protecting the contact rollers **6** from the processing fluid. The sealing lips **23** thereby prevent undesired liquid leakage as a result of a varying bath surface level for example.

Fig. 8 illustrates a cross sectional lateral view of the second embodiment of a horizontal processing line in accordance with the present invention in another variant. The processing line consists of a collecting tank **12** having three different modules **M1, M2** and **M3** that are each characterized by various anode and cathode arrangements.

The processing modules are disposed alongside the conveying path of the foil strip **1** leading through the device so that the foil strip **1** is capable of passing sequentially through the discrete modules, starting with module **M1.** Deviating reels **18** are disposed before and between the modules.

The foil strip **1** is introduced into the module **M1** by means of a deviating reel **18.** The module **M1** substantially consists of a pivoted anode roller **4** having an ion-permeable isolation **13**, the anode **4** being partially immersed into the processing liquid. The liquid surface level is indicated at **15.** The coating **13** between the anode roller **4** and the foil strip **1** serves for insulation and can thereby be supplied with processing liquid provided from the inner volume of the roller **4.** The module **M1** further includes a cover cap **20** that protects the contact roller **6** against being wetted with processing liquid. On this cover cap **20** there are disposed, upstream of the anode **4** as viewed in the direction of transport of the foil strip **1,** a single first contact roller **6** that is electrically insulated against the anode **4,** and downstream of said anode **4** a second contact roller **6** that is electrically insulated against said anode **4.** Said module **M1** is preferably used if the foil strip **1** is to be metal plated on one side only. The anode holder **5** and the contact roller **6** are combined into one unit for a more compact construction.

After metal plating has been completed, the foil strip **1** is conveyed out of the module **M1** and via a deviating reel **18** into the second module **M2**. The module **M2** comprises an anode arrangement consisting of a pivoted anode roller **4** having an ion-permeable isolation **13** and of a curved anode **4'** also having an ion-permeable isolation **13** that projects out of the liquid surface level **15** and conforms to the orientation of the foil strip **1**. Upstream and downstream of the anode arrangement there are located two identical contacting arrangements that are disposed on the cover cap **20** so as to be electrically insulated against the anode **4**. These arrangements consist of a contact roller **6** and of a contact brush **14** located on the opposite side of the contact roller **6**.

After the foil strip **1** has been plated on its two sides in module **M2**, it is conveyed via a deviating reel **18** into the third module **M3**. Module **M3** is substantially similar to module **M2**. Contact rollers **6** are used in lieu of the contact brushes **14**, said contact rollers being mounted on the same supporting arm as the anode **4"** against which they are electrically insulated. The shape of the curved anode **4"** clearly conforms to that of the rotatable anode **4**. This module **M3** constitutes a preferred embodiment if the use of contact brushes is to be excluded since the contact between the anode **4"** and the work pieces **1** is more uniform and longer than at the anode **4'**, thus resulting in a more uniform coating. Upon completion of the treatment in the third module **M3** the foil strip **1** is conveyed out of the processing line via a deviating roller **18**.

Fig. 9 illustrates a cross sectional side view of a variant of the horizontal processing line of **Fig. 8**.

The identical modules **M4** and **M5** substantially resemble module **M3** shown in **Fig. 9**, the lower curved anode **4"** having been dispensed with. The modules are suited for use in the cases in which the foil strip **1** is to be coated on both sides. In the modules **M4** and **M5**, the contact rollers **6** are mounted to an anode holder **5** so as to be electrically insulated.

The various embodiments described can also be combined in other manners as those described herein above. The sealing member with the sealing lips **23**

shown in **Fig. 7** may e.g., also be used in the variant shown in **Fig. 8** and in **Fig. 9.**

It is understood that the examples and embodiments described herein are for illustrative purpose only and that various modifications and changes in light thereof as well as combinations of features described in this application will be suggested to persons skilled in the art and are to be included within the disclosure of the described invention and within the scope of the appended claims. All publications, patents and patent applications cited herein are hereby incorporated by reference.

Reference numerals:

1	work piece (foil strip)
2	electrolytic cell top
3	electrolytic cell bottom
4	counter electrodes, anodes
5	counter electrode holders, anode holders
6	contacting electrodes, contacting rollers
7	sealing rollers
8	auxiliary sealing rollers
9	sealing wall
10	module wall, cell wall
11	electrolyte feed line
12	collecting tank
13	ion-permeable isolation
14	contact brushes
15	bath surface level
16	sealing roller bearing
17	electrolyte discharge line
18	deviating roller
19	bearing surface for the upper anode holder
20	cover cap
21	partition member
22	pinch roller
23	sealing lip
24	inner partition wall
25	drive rollers
M, M1 - M5	processing modules